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NASA TECHNICAL MEMORANDUM

NASA TM X-71588

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(NASA-TM-X-71588) REMOTE PROFILING OF LAKE ICE THICKNESS USING A SHORT PULSE RADAR SYSTEM ABOARD A C-47 AIRCRAFT (NASA) ~~4~~ 5 p HC $3.00 CSCL 08L

N74-29723

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G3/13 54439

REMOTE PROFILING OF LAKE ICE THICKNESS USING A SHORT PULSE RADAR SYSTEM ABOARD A C-47 AIRCRAFT

by Dale W. Cooper, John E. Heighway, Donald F. Shook, and Russell J. Jirberg
Lewis Research Center
Cleveland, Ohio 44135

and

Roger S. Vickers
Stanford Research Institute
Menlo Park, California

TECHNICAL PAPER proposed for presentation at
1974 Earth Environment and Resources Conference
Philadelphia, Pennsylvania, September 10-12, 1974

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Dale W. Cooper, John E. Heighway, Donald F. Shook, and
Russell J. Jirberg of NASA - Lewis Research Center, Cleveland, Ohio

Roger S. Vickers presently at Stanford Research Institute
Menlo Park, California

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INTRODUCTION

During the past winter (73-74), NASA in conjunction with the National Weather Service, U. S. Coast Guard and Army, has been involved in the demonstration of a lake ice information system to help facilitate lake shipping. Prior to and during this last ice season, Army OV-1 aircraft with side looking radar (SLAR) were used to determine ice location, patterns and movement on the Great Lakes. The SLAR is very sensitive to surface roughness and discontinuities, but has not been able to give good indications of ice thickness. Ice auger teams have been used for ground truth to supplement the SLAR data, but these measurements are laborious, time consuming, weather dependent, and cannot be done on a large enough scale to map an entire lake in a reasonable amount of time.

During winter (72-73) a short pulse S band radar system which had previously been used to measure snow depth was tried on ice in Lake St. Clair and Whitefish Bay using a Sikorski H-53 helicopter (ref. 1). Only a few points up to an altitude of 300 feet were taken, but these verified the principles. This paper describes the design and operation of new short pulse radar systems which were developed for use at higher altitudes on the NASA C-47 aircraft during the past winter (73-74).

SYSTEM DESIGN AND OPERATION

Two ice profiling systems were designed and tested on the C-47 aircraft. The S band system was made to use either random noise or c. w. modulation at 2.8 GHz. The random noise modulation was used to avoid the possibility of coherent interference between the transmitted pulse and other stray signals.

The C band system was identical to the S band system except it operates at 6.0 GHz and does not have random noise modulation. The C band antennas were orthogonally polarized to the S band antennas to minimize interaction. Both systems were operated simultaneously and displayed on the sampling oscilloscope.

Figure 1 shows the block diagram of the S band system. The noise source generates 40 milliwatts of noise power while the oscillator generates 20 milliwatts of power at 2.8 GHz. The mixer is driven with a one nano-sec pulse with a peak amplitude of about 2V. Double mixing (the output of the mixer was again mixed with the nano-sec pulse) was used to provide an output pulse more nearly free of feed-thru. A 20 watt TWT was used to amplify the signal for transmission. The nano-sec pulser was constructed from step recovery diodes which sharpened the forward and trailing edges of the pulse. The clock was typically run at 100 kHz. The delay compensated for the round trip time of the pulse from the aircraft to the ice and back. Manual adjustments had to be made on the delay to offset aircraft altitude changes. The four C and S bands receiving antennas were located in a pod below the wing in a nadir position. The low noise receiver amplifiers, combiners, and detectors were all contained in the pod. A TWT receiver amplifier was used at C band while the S band amplifier was solid state. Data were taken with an oscilloscope camera which photographed the 1 GHz. sampling scope and the output was also recorded on magnetic tape.

The principle of operation is based on the fact that a return signal will be composed of a pulse return from the top of the ice and another, delayed in time, from the ice-water interface. The delay time between these two pulses directly gives the ice thickness when compensated by the slower r. f. propagation through the ice. On smooth flat ice the observed area would be very small, on the order of the antenna aperture. As discontinuities and roughness occur on the ice a larger observed area is involved. Figure 2 shows a typical C band and S band return.

RESULTS AND CONCLUSIONS

Calibration of the ice measuring system was done at Brevoort Lake in the upper peninsula west of the Straits of Mackinac. An extended ice auger team survey found the ice in the survey area to be 21 to 24 inches; this result checked with the results from the remote ice measuring system. The ice auger team has found that the bottom surfaces of lake ice samples are almost always smooth.

The S band system operated continuously, while the C band system was intermittant, apparently due to sub-system difficulty. The C band system was less powerful and required smoother ice for operation. The c. w. S band system was superior, and the noise modulation proved to be unnecessary.

Typically flight altitudes of 4000 feet were used, but the S band system was usable at 7000 feet which allows flights in poor weather conditions. Snow storms, fog and snow covered ice were encountered, but did not effect the measurements. However, water on the ice surface from rain or melting precluded measurements at those locations because the pulse would not penetrate the ice.

(1) Vickers, R. S.; Heighway, J.; and Gedney, R.: "Airborne Profiling of Ice Thickness Using a Short Pulse Radar", NASA TM X-71481; 1974.

An ice thickness of more than four inches is required to separate the two return pulses, while the system accuracy typically is ±1 inch. Ice thickness of 36 inches has been measured, but this was not system limited. It was the thickest ice encountered. Flights were made routinely during the (73-74) winter season, which supplemented the SLAR data. A typical map is shown in Figure 3. The areas near Duluth, Thunder Bay and Soo are of particular interest to the shippers. Wind rows, pressure ridges and leads were evident from the system return and refinements will be required to obtain more information concerning them. With this system unambiguous ice thickness can readily be inferred from noncomplex ice sheets.

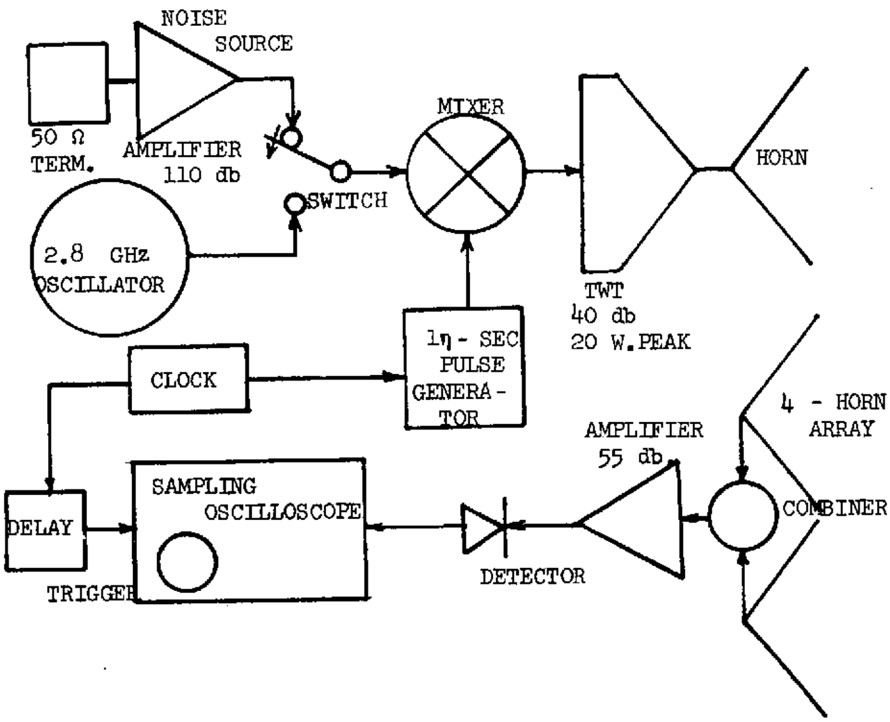

FIGURE 1. Block Diagram of Short Pulse Radar System - S Band

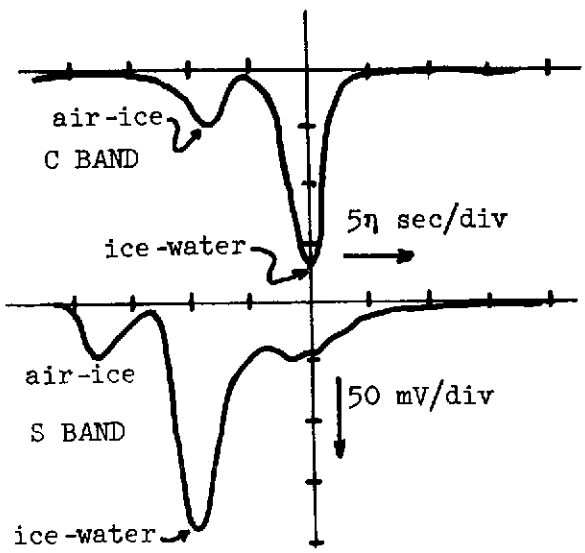

FIGURE 2. Typical C and S Band Returns from 24 inches of Ice. Pulse Offset is Due to Unequal Cable Lengths.

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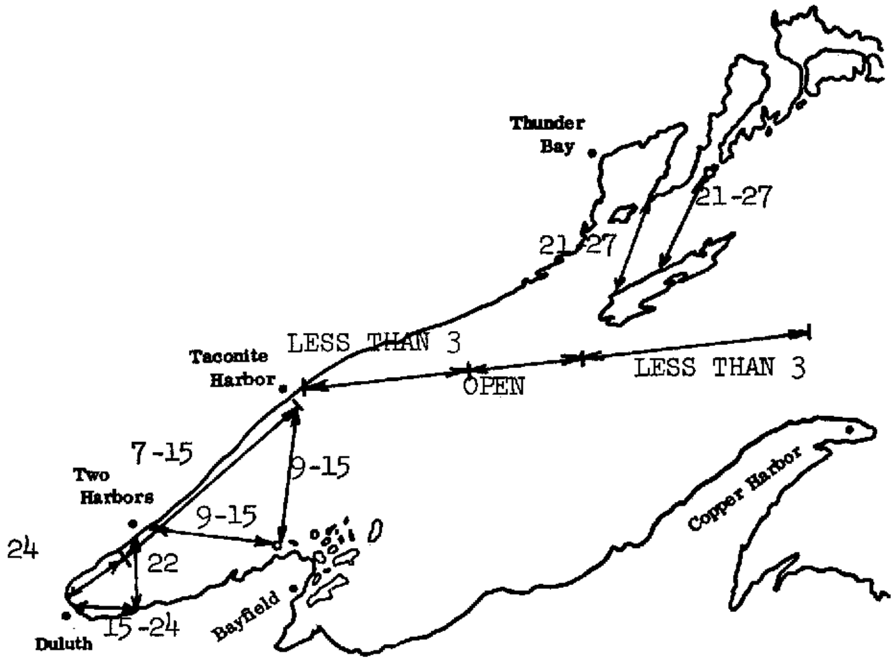

LAKE SUPERIOR SUMMARY ICE CHART

DATE: APRIL 8&9 1974

TIME:

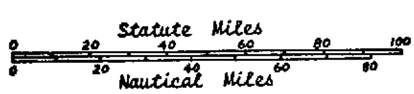

FIGURE 3. Ice Thickness in Inches on Western Lake Superior taken from C-47 Aircraft at 4000 to 6900 feet